

Evaluation of Energy Cost of Major Food Crop Production in Enugu State, Nigeria

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ABSTRACT

The energy cost of producing major food crops in Enugu State of Nigeria were determined and evaluated. Energy analysis of producing yam, cassava, maize, coco yam, rice, groundnut, black beans and Bambara nut were carried out based on field operation, fertilizer application and harvesting. Operational energy used in form of direct and indirect energy and energy sources involved in the production process were computed. The major issue of concern is that farmers use more energy to increase output but they do not have enough knowledge on most efficient energy inputs to use. The research study was planned on the basis of investigative survey research approach which involving the use of questionnaire and personal interview with the major produce of the selected crops during the field trips. In carrying out this investigative survey, the author visited thirty-two (32) farmers from each of the nine LGA selected within the stipulated time. The results showed that land preparation operation activities consumed the highest percentage of energy for producing maize, coco yam, rice, groundnut, black beans and Bambara nut (34.76 %, 32.50 %, 38.35 %, 31.18 %, 28.81 % and 28.42 %) except on cassava and yam that recorded highest production energy at harvesting (21.65 %) and planting (76.03 %) respectively. It was gathered also that direct, renewable and non-commercial energy used were higher than indirect, non-renewable and commercial energy used in producing those selected crops in the area. The low proportion of non-renewable energy indicated that farmers in the study area depend on manual labour in producing the selected food crops.

Keywords: energy cost; food crops; production energy

1. INTRODUCTION

Agriculture provides 41% of Nigeria's total gross domestic product (GDP) in 1999. This percentage represented a normal decrease of 24.7% from its contribution of 65.7% to the GDP in 1957. This decrease will continue because of the fact that when economic improves, the relative size of the agricultural sector usually becomes poor [2].

The effects of agricultural activities on the environment are of growing concern. Particularly, the consumption of fossil energy, increasing energy price, and the current debate on human influences on climate change and global warming hold strong link to agriculture. Thus, the need for an evaluation of

energy inputs use efficiency in Nigeria agriculture. This is because, efficient energy use in agriculture is one of the conditions for commendable agricultural production, since it provide financial savings, fossil fuels protection and air pollution reduction [9].

In Nigeria, like any other developing countries there is lack of data on energy expenditure and returns in crop production [1]. It is invested in various form such as mechanical (Farm machines, human power and animal draft) chemical fertilizer (pesticides and herbicides) and electrical.

Though fewer attention is given to energy expenditure in crop production in Nigeria, the energy consumption in agriculture activities is becoming very important to the extent that increasing demand for food production to sustain the request from an ever-increasing population. Nigeria's wide range of climate change allows it to produce different food crops [10].

The staple food crops include cassava, yams sweet potatoes, coco-yams, corn, cowpeas, bean, millet, rice wheat, sorghum and a variety of fruit and vegetables. Although grains make up about 80% of the world's food supply, approximately half of the world's population cannot afford grains. For this reason, prices of grain have not increase greatly during the past decade. However, due to biofuel production, especially corn ethanol, food shortages and food prices have recently moved from 10% to 50% [10].

As the population continues to grow, greater population is being place on resources essential for food production, including fossil energy. The human population increases tremendously, while food production did not follow suit. The result led to the current food shortage within the country. Low and unavailability of land, water, energy and biological resources needed for agriculture, have been increasing, which hinder agricultural production [2].

Farmers rely on different sources of energy and power. These sources range from animal, human, and little of mechanical power as shown in Table 1, which include wind, tidal and water energy to wood, coal, gas, oil, solar, and nuclear source of fuel and power, using fossil fuel resource enable a nation to feed high number of human and increases quality of life in many ways, including protection from malnourishment and numerous other disease [11].

Table 1: Source of power for various primary land preparation operations in various countries

Country	Human energy	Draught animal power	Mechanical power
Nigeria	86	4	10
Botswana	20	40	40
Zimbabwe	15	30	55
Tanxania	80	14	6
Kenya	84	12	4
Ethiopia	10	80	10
Zambia	55	15	30
Swazi land	15	35	50
Ugand	70	20	10
China	22	26	52
India	18	21	61

Source: Odigboh, (2002)

The current high rate of energy for agriculture is related to many factors, which include rapid population growth, development, and high resource-consumption rates. The high energy expenditure also causes environmental degradation [12]. The energy use in agriculture has been increasing faster than the rate of growth of the world population. From 1979 to 1997, energy expenditure is growing arithmetically in every 30 years whereas the world population has been growing arithmetically in every 40-50 year. In no distant time, energy expenditure will be growing arithmetically in every 32 years while the population density is estimated to be double in about 50-60 years [11]

The two billion people, approximately, who live in the world's developed country consume about 70.5% of the world's fossil energy annually, while about five billion people in growing nations use only 30% [16]. The growing countries that have high rates of population growth were mostly using fossil fuel in agricultural production to meet increased demand for food and fiber.

Food energy efficiency

Food energy efficiency strongly influences the food supply chan. Food energy efficiency refers to the ability to reduce energy loss in food production processes to the barest minimum. Minimization of energy loss is such agricultural production processes such as

harvesting, drying, storage, handling transport; cooking, recycling etc. has high capacity to increase food supply. It is widely viewed that introduction of effective agricultural mechanization in the developing countries with food energy efficiency have the tendency to promote sustainable global food demand and supply in future [3]. FAO (2012) report, agrees that increase in food demand are due to population growth and changes in diets. It has recommended that to meet global food demand in 2050, agricultural production must be 60% higher by weight than in 2005 level, stressing that the overall demand for agricultural products (including food, fibre and bio-fuels) is expected to increase 1.1% per year.

Energy input-output analysis in food production

The energy input for the crop production differs to a large extent from area to area and also depending on the level of mechanization. Commercial crop production in modern areas are characterized by the high input of fossil energy (fuel and electricity) which is consumed as direct energy and as indirect energy (fertilizers, pesticides, machinery, etc) [5].

In the past decade, with increase in energy inputs in agriculture, an equivalent increase in crop yield occurred. Jekayinfa and Bamgboye (2007) suggested that the energy use efficiency of over traditional cropping systems have been sharply going down ward in recent years due to energy inputs increasing faster than energy output as a result of the growing dependency on inorganic fertilizers and fossil fuels. Energy use analysis from the literature have shown that different researchers who used different methods for evaluating human energy reported several values of the energy content for manual labour. Hence, there is no universally accepted energy value of manual labour. Sustainable direct energy is required to perform various tasks related to crop production processes such as land preparation, irrigation, harvest, post-harvest processing, transportation of agricultural inputs and outputs. In other word, high level of direct energy such as fuel and electricity are needed to be used at farm for crop production [5]. Unlike direct energy which is directly consumed at the farm, indirect energy is not directly consumed at the farm rather are the energy used in the manufacture, packaging and transport of fertilizer, seeds, machinery production and pesticides [8].

Role of fossil energy in food crop production

Agricultural production in both developed and developing nations need about 2.5 to 168.5 million Kcal/ha. In developed nations, the fossil energy need for mechanization to reduce the human input are much whereas in the developing nations the fossil energy need for labour are high. Most of the fossil energy expended in agricultural production in both developed and developing nations is in form of oil and natural gas. Oil is very important for farm machinery and natural gas is also needful for the production of nitrogen fertilizers [13].

The total amount of fossil energy consumed in the world is about 473.9 quads [2]. Almost 70.5% are used in developed nations and 29.5% are used in developing nation. The population density in developed nations is about 2 billion while more than 4.2 billion resides in developing nations [16].

Up to 40.5 quads of fossil energy are used to make food available for people in developed nations, but, about 16.2 quads of this population are used for crop and livestock production [11]. The remaining 23.8 quads in developed nations are used for preparation, processing of food, packaging, and distribution. In developing nations, almost 16 quads are used for agricultural production. Most of the cooking in developing nations is carried out using biomass energy (Fuel wood, crop residues and dung) [11].

From 2.5 to 3.5 Kcal of biomass energy are used to prepare 1.5Kcal of food in developing nations [15]. Therefore, total energy in the food system in developing nations is between 48.8 and 75.6 quads per year.

The total energy in the food system in developed nations is approximately 4.5 Kcal that are used to supply 1.5 Kcal of food, while in developing nations the ratio is about 1.5 Kcal which was used to supply 1.5 Kcal of food [11]. In developed nations farmers utilize an average of 3,500 Kcal of food per person per day, whereas farmers in developing nations use 2,400 Kcal of food per day per person [2]. This 1,100 fewer Kcal utilized per day in developing nations reflects many young farmers in developing nations receiving fewer calories per day.

Evaluation of energy cost of selected food crops production in Enugu State, Nigeria. With the current increase in world population, energy consumption needs effective planning. Crop yield and food supplies to consumers are directly linked to energy, which means sufficient energy is needed in the time for adequate food crop production. One way to optimize energy consumption in agriculture is to determine the efficiently of methods and technique used. Crop-yield is directly proportional to the energy input. To adequately evaluate crop production energy requirements and be able to choose alternative crop production systems, energy data need to be collected for mechanical (Farm machines, human power and animal draft), chemical fertilizer (pesticides and herbicides) and electrical [14]. The amount of energy used in agricultural production, processing and distribution needs to be adequate in order to feed the rising population and to meet other social and economic goals. Information on comparative use of

different energies is lacking and most of the farmers do not have enough knowledge on the most efficient energy inputs. Consequently, it is neither possible to identify viable energy inputs and option in the production process nor plan for their conservation. Under these situations, an input-output energy analysis provides planners and policy maker an opportunity to evaluate economic interaction of energy use. This information is required in order to make deductions on the efficiencies of the energies and suggestion on which energy sources or their combinations need to be used and at what levels [6]. Also this would serve as a data bank for any related study. The main aim of this research work is to evaluate the energy cost of selected food crop production in Enugu State, Nigeria. The specific objectives are to determine, analyze and the output /input ratio of energy cost input per field operation for various selected food crops.

2. MATERIAL AND METHODS

This research study was carried out in Enugu State of Nigeria. Enugu State is located in South Eastern Nigeria and comprises of seventeen (17) local governments that were grouped into three senatorial districts. The farmers visited were the ones producing yam, cassava, maize, coco yam, rice, groundnut, black beans and Bambara nut in abundant within the zones selected. The Study was carried out from July, 2018 to February 2019 within the places mentioned below.

Design of the Research Study

The research study was designed on the basis of investigative survey Research Approach (ISRA). The investigative survey research approach for obtaining the data for this research entails the schedule of visits to places of interest but relevant to this research study. The task to be accomplished during such visit included the following

1. Physical visit to places where yam, cassava, maize, coco yam, rice, groundnut, black beans and Bambara nut are producing in abundant.
2. Administration and completion of questionnaire on quantity of crops produced, hectare of land covered and the input on producing the above mentioned crops.
3. Relevant oral interviews with the farmers involved.

The data sought for in each place visited were based on observation, opinions from crop producers' experts and information from questionnaires. The data obtained were analyzed and was done using descriptive statistics and energy use efficiency which was estimated by equation 2.1 below.

$$\text{energy efficiency} = \frac{\text{energy output (MJha}^{-1}\text{)}}{\text{energy input (MJha}^{-1}\text{)}} \quad [5] \quad 2.1$$

The energy equivalent of unit input were expressed in mega joule (MJ) and total input equivalent was calculated by summing of energy equivalence of all inputs. Energy analysis was performed based on field operations (land preparation, planting, fertilizing, spraying and harvesting) as well as on the direct (fuel and human labour) and indirect (machinery, fertilizer, pesticide and seed) energy sources involved in the production process.

Description of the Questionnaire

The questionnaire designed for this study was in two different parts. They include the bio data of the farmer interviewed or filled the questionnaire and quantity of crops produced, hectare of land covered and the input on producing the above mentioned crops. The main targets of this questionnaire were the crop producers and also places that produced the above crops in abundant. Nine local government in Enugu State of Nigeria which include Udi, Oji river, Agwu, Nkaun east, Nkanu West, Isi Uzo, Igbo etiti, Uzo Uwani, and Udenu were visited. The questionnaire seeks information on the type of crops grown, quantity of crops produced, sources of power used in producing those crops, hectare of land covered and other inputs in producing the crops.

Crops Producers Visited and Method of Data Collection

In carrying out this investigative survey, thirty-two (32) farmers from each of the nine LGA selected were visited within the stipulated time. During the visit, questionnaires were administered to collect appropriate data. Data collected was based on the major researching areas chosen. Also personal interviews were conducted to get some vital information necessary for this research study. The direct producers of the above mentioned crops, farm managers and crop processors within the farm and other staffs of the farm were in the best position to give the required information by virtue of their position and experience.

Types of farming and power sources in the area visited

The farmers visited were practicing two major farming types, which include subsistence and commercial farming activities but subsistence predominated within the areas visited. Farmers visited rely on different sources of energy and power in their crop production. These sources range from human, animal, machines and others. Though, most of the farmers visited rely on human powers except places like Uzo Uwani and Isi Uzo local government.

Energy analysis of crop production

Energy analysis of the above mentioned crops were performed based on field operation such as land preparation, planting, sanitation (weeding and application of herbicide), fertilizer application and harvesting. Operational energy used in form of direct (fuel and human labour) and indirect (machinery, fertilizer, manure, herbicide and planting materials) and energy sources involved in the production process were computed. The analysis of the data collected with respect of the eight food crop production in the study area was reported. The major issue of concern is that farmers use more energy to increase output but they do not have enough knowledge on most efficient energy inputs to use. Thus, an input-output energy analysis provides farmer and policy makers an opportunity to evaluate economic intersection of energy use. Direct and indirect types of energy are required for agricultural production.

3. RESULTS AND DISCUSSION

The investigative survey on the energy cost in producing yam, cassava, maize, coco yam, rice, groundnut, black beans and Bambara nut crop in Enugu State of Nigeria was carried out. The average data obtained from the questionnaires issued and oral interview to the above crop producers are shown in the tables below.

Table 2: Energy cost for field operation of cassava production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	19.25
ii.	Burning (hr)	16	31.36	2,400	0.96
iii.	Packing of debarked stumping (hr)	120	235.2	18,000	7.22
iv.	Tillage (hr)	2	125.40	10,000	4.01
	Total				31.5
2.	Planting				
i.	Preparation of cutting for planting (hr)	32	62.72	4800	1.93
ii.	Planting (hr)	160	313.60	24000	9.62
	Total				11.55
3.	Sanitation				
i.	Weeding manually (hr)	320	627.20	48,000	19.25
ii.	Herbicides Application (litres)	8	15.68	1,200	0.48
	Total				19.73

4.	Fertilizer and Manure application (kg)	160	313.60	24,000	9.62
5.	Harvesting (kg)	360	705.60	54000	21.65
6	Machinery application (hr)	3	188.10	15,000	6.01
	G. Total	1,501	3,245.66	249,400	100.00
	Yield (kg)	19718	71940	649200	

Table 3: Energy cost for field operation of maize production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	18.87
ii.	Burning (hr)	16	31.36	2,400	0.95
iii.	Packing of debrired stumping (hr)	120	235.2	18,000	7.08
iv.	Tillage (hr)	4	250.80	20,000	7.86
	Total				34.76
2.	Planting				
i.	Preparation of cutting for planting (hr)	32	62.72	4800	1.89
ii.	Planting (hr)	160	313.60	24000	9.44
	Total				11.33
3.	Sanitation				
i.	Weeding manually (hr)	320	627.20	48,000	18.87
ii.	Herbicides Application (litres)	4	7.84	600	0.24
	Total				19.11
4.	Fertilizer and Manure application (kg)	160	313.60	24,000	9.44
5.	Harvesting (kg)	360	705.60	54000	21.23
6	Machinery application (hr)	4	250.8	20,000	7.86
	G. Total	1502	3,308.36	254400	100.00
	Yield (kg)	60776	25560	711600	

Table 4: Energy cost for field operation of yam production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	4.6
ii.	Burning (hr)	16	31.36	2,400	0.23
iii.	Packing of debris and stumping (hr)	120	235.2	18,000	1.73
iv.	Tillage (hr)	4	250.80	20,000	1.92
	Total				8.48
2.	Planting				
i.	Preparation of cutting for planting (hr)	80	156.80	11,226.90	1.08
ii.	Planting (hr)	520	1019.20	781,400	74.95
	Total				76.03
3.	Sanitation				
i.	Weeding manually (hr)	320	627.20	48,000	4.6
ii.	Herbicides Application (litres)	4	7.84	600	0.06
	Total				4.66
4.	Fertilizer and Manure application (kg)	160	313.60	24,000	2.30
5.	Harvesting (kg)	360	705.60	54,000	5.18
6	Machinery application (hr)	7	438.90	35,000	3.36
	G. Total	1,911	4,414	1,042,626.9	100.00
	Yield (kg)	64,000	42,750	125,360	

Table 5: Energy cost for field operation of coco yam production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	17.65
ii.	Burning (hr)	16	31.36	2,400	0.88
iii.	Packing of debris and stumping (hr)	120	235.2	18,000	6.62
iv.	Tillage (hr)	4	250.80	20,000	7.35

	Total				32.50
2.	Planting				
i.	Preparation of cutting for planting (hr)	70	137.20	10,499.92	3.86
ii.	Planting (hr)	250	490.0	37,499.70	13.79
	Total				17.65
3.	Sanitation				
i.	Weeding manually (hr)	360	705.60	54,000.57	19.85
ii.	Herbicides Application (litres)	4	7.84	600	0.22
	Total				20.07
4.	Fertilizer and Manure application (kg)	160	313.60	24,000	8.82
5.	Harvesting (kg)	180	352.80	27,000.50	9.93
6	Machinery application (hr)	6	376.20	30,000	11.03
	G. Total	1,490	3,527.80	272,000.69	100.00
	Yield (kg)	32400	79200	1174800	

Table 6: Energy cost for field operation of rice production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	20.35
ii.	Burning (hr)	16	31.36	2,400	1.02
iii.	Packing of debris and stumping (hr)	134	261.90	20,050	8.50
iv.	Tillage (hr)	4	250.80	20,000	8.48
	Total				38.35
2.	Planting				
i.	Preparation of cutting for planting (hr)	50	98.0	7500.94	3.18
ii.	Planting (hr)	90	176.40	13,500.90	5.72
	Total				8.90
3.	Sanitation				
i.	Weeding manually (hr)	320	627.20	48,000.53	20.35
ii.	Herbicides Application (litres)	3	5.88	450.64	0.19
	Total				20.54

4.	Fertilizer and Manure application (kg)	100	196.0	15,000.88	6.36
5.	Harvesting (kg)	220	431.20	33,000.74	13.99
6	Machinery application (hr)	6	376.20	30,000	12.72
	G. Total	1,249	3,055.44	235,854.63	100.00
	Yield (kg)	19800	68320	616800	

Table 7: Energy cost for field operation of groundnut production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	16.93
ii.	Burning (hr)	16	31.36	2,400	0.85
iii.	Packing of debris and stumping (hr)	120	245.9	18,800.73	6.35
iv.	Tillage (hr)	3	250.80	20,000	7.05
	Total				31.18
2.	Planting				
i.	Preparation of cutting for planting (hr)	120	245.90	18,800.73	6.35
ii.	Planting (hr)	300	588.0	45,000.64	15.87
	Total				22.22
3.	Sanitation				
i.	Weeding manually (hr)	320	627.20	48,000	16.93
ii.	Herbicides Application (litres)	2	4.0	306.12	0.11
	Total				17.04
4.	Fertilizer and Manure application (kg)	160	313.60	12,245.80	4.32
5.	Harvesting (kg)	300	588.0	45,000.64	15.87
6	Machinery application (hr)	5	313.5	25,000	8.82
	G. Total	1,666	3,835.46	283,554.66	100.00
	Yield (kg)	63850	21552.72	629720	

Table 8: Energy cost for field operation of black beans production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	17.46
ii.	Burning (hr)	16	31.36	2,400	0.87
iii.	Packing of debris and stumping (hr)	120	245.9	18,800.73	6.84
iv.	Tillage (hr)	2	3.92	10,000	3.64
	Total				28.81
2.	Planting				
i.	Preparation of cutting for planting (hr)	120	245.90	18,800.73	6.84
ii.	Planting (hr)	220	431.20	33,000.74	12.00
	Total				18.84
3.	Sanitation				
i.	Weeding manually (hr)	340	666.40	51,000.59	18.55
ii.	Herbicides Application (litres)	3	5.88	450.64	0.16
	Total				18.71
4.	Fertilizer and Manure application (kg)	150	294.0	22,500.82	8.18
5.	Harvesting (kg)	300	588	45,000.64	16.37
6	Machinery application (hr)	5	313.5	25,000	9.09
	G. Total	1,596	3,453.26	274,954.89	100.00
	Yield (kg)	46450	29925	636200	

Table 9: Energy cost for field operation of Bambara nut production

N/S	Operations	Quantity	Energy Equivalent (MJ)	Energy Cost (N)	Percentage Energy Cost (%)
1.	Land Preparation (hr)				
i.	Land clearing (hr)	320	627.20	48,000	17.18
ii.	Burning (hr)	16	31.36	2,400	0.87
iii.	Packing of debris and stumping (hr)	120	245.9	18,800.73	6.73
iv.	Tillage (hr)	2	3.92	10,000	3.64
	Total				28.42

2.	Planting				
i.	Preparation of cutting for planting (hr)	120	245.90	18,800.73	6.73
ii.	Planting (hr)	220	431.20	33,000.74	12.02
	Total				18.75
3.	Sanitation				
i.	Weeding manually (hr)	340	666.40	51,000.59	18.52
ii.	Herbicides Application (litres)	3	5.88	450.64	0.16
	Total				18.74
4.	Fertilizer and Manure application (kg)	160	313.60	24,000.53	8.59
5.	Harvesting (kg)	320	627.20	48,000	17.18
6	Machinery application (hr)	5	313.5	25,000	8.95
	G. Total	1,626	3,512.06	279,453.96	100.00
	Yield (kg)	53000	25697	623320	

Table 10: Energy Cost from Different Energy Sources for Cassava and Maize Production

Cassava			Maize		
Energy forms	Energy cost (N)	Percentage cost	Energy forms	Energy cost (N)	Percentage cost
Direct	228600	70.00	Direct	217800	61.00
Indirect	96000	30.00	Indirect	13800	39.00
Total energy cost	324600	100.00	Total energy cost	355800	100.00
Renewable	238,200	73.00	Renewable	222400	62.50
Non-renewable	36400	27.00	Non-renewable	133400	37.50
Total energy cost	324600	100.00	Total energy cost	355800	100.00
Commercial	86400	28.00	Commercial	133400	37.50
Non-commercial	223200	72.00	Non-commercial	212400	62.50
Total energy cost	309600	100.00	Total energy cost	345800	100.00

Table 11: Energy Cost from different Energy Sources for Yam and Coco yam Production

Yam			Coco yam		
Energy forms	Energy cost (N)	Percentage cost	Energy forms	Energy cost (N)	Percentage cost
Direct	19500	31.00	Direct	275400	47.00
Indirect	431200	69.00	Indirect	312000	53.00
Total energy cost	626800	100.00	Total energy cost	587400	100.00

Renewable	541600	86.00	Renewable	506400	76.00
Non-renewable	85200	14.00	Non-renewable	81000	24.00
Total energy cost	626800	100.00	Total energy cost	587400	100.00
Commercial	85200	29.00	Commercial	81000	23.00
Non-commercial	208400	71.00	Non-commercial	266400	77.00
Total energy cost	293600	100.00	Total energy cost	347400	100.00

Table 12: Energy Cost from different Energy Sources for Rice and Ground nut Production

Rice			Groundnut		
Energy forms	Energy cost (N)	Percentage cost	Energy forms	Energy cost (N)	Percentage cost
Direct	217,200	70.43	Direct	221,750	70.42
Indirect	91,200	29.57	Indirect	93,200	29.58
Total energy cost	308,400	100.00	Total energy cost	314,860	100.00
Renewable	226,290	73.38	Renewable	231,100	73.37
Non-renewable	34580	26.62	Non-renewable	35310	26.63
Total energy cost	308,370	100.00	Total energy cost	314,860	100.00
Commercial	82100	27.90	Commercial	83,800	27.91
Non-commercial	212,040	72.10	Non-commercial	216,500	72.09
Total energy cost	294,220	100.00	Total energy cost	300,300	100.00

Table 13: Energy Cost from different Energy Sources for Black beans and Bambara nut Production

Black beans			Bambara nut		
Energy forms	Energy cost (N)	Percentage cost	Energy forms	Energy cost (N)	Percentage cost
Direct	224,100	70.45	Direct	219,550	65.50
Indirect	94,080	29.55	Indirect	92,180	34.50
Total energy cost	318,100	100.00	Total energy cost	311,660	100.00
Renewable	233,430	70.38	Renewable	228,700	69.39
Non-renewable	35,700	29.62	Non-renewable	34,950	30.61
Total energy cost	318,100	100.00	Total energy cost	311,640	100.00
Commercial	84,700	27.92	Commercial	82,900	27.89
Non-commercial	218,800	72.08	Non-commercial	214,300	72.11
Total energy cost	303,400	100.00	Total energy cost	297,220	100.00

Table 14: Total Energy Inputs, Energy Outputs and Energy Use Ratio of Different Food Crops

Energy input and output in all field operations	Different food crops							
	Cassava	Maize	Yam	Coco yam	Rice	Groundnut	Black beans	Bambara nut
Total energy input(ei) MJHa-1	11007.58	15253.16	22662.66	35331.56	13209.96	13727.85	22662.66	17665.78
Total energy output (eo)MJHa-1	71940	25560	42750	79200	68320	21552.72	29925	25697
Overall energy used ratio OEUR	6.5	1.68	1.89	2.2	5.2	1.57	1.32	1.45

The mean values of various field operations and quantity of energy input per hectare for the eight food crops considered were presented in Tables 2 to 9. It was seen from the result of field operation that more energy and time were consumed in land clearing, fertilizer procurement, weeding and harvesting while ploughing and harrowing, burning, planting and application of saw dust for mulching consumed less energy and time. The Tables also showed the percentage computed valued of energy cost resource input for various field operations for the various food crops and was categorized as land preparation operations, planting, sanitation, fertilizer and manure application, harvesting and machinery applications. The results revealed that land preparation operation activities consumed the highest percentage of energy for producing maize, coco yam, rice, groundnut, black beans and Bambara nut (34.76 %, 32.50 %, 38.35 %, 31.18 %, 28.81 % and 28.42 %) except on cassava and yam that recorded highest production energy at harvesting (21.65 %) and planting (76.03 %) respectively. The variation in energy cost of cassava and yam production could be due to high intensive and excessive energy use during soil breaking by harvesting and tillage implement used during the operations. Fertilizer and manure application showed the least percentage of energy cost on producing yam, coco yam, rice, groundnut, black beans and bambara nut (2.30 %, 8.82 %, 6.36 %, 4.32 %, 8.18 % and 8.59 %) except on cassava and maize production that recorded least production energy at machinery applications (6.01 % and 7.86 %). The amount of energy needed for fertilizer and manure application was generally low because the farmers in the study area practice shifting cultivation, therefore, the soil need small or non-fertilizer for crop production

The Tables 10 to 12 showed the direct, indirect, renewable, non-renewable, commercial and non-commercial energy sources used in the production of the selected food crops in the study area. It was recorded that the direct energy input in production of cassava, maize, yam, coco yam, rice, groundnut, black beans and bambara nut were 70%, 31%, 61%, 70.45%, 47%, 70.42%, 70.45% and 65.50% compared to 30%, 69%, 39%, 29.55%, 53%, 29.58%, 29.55% and 34.50% of indirect energy used for producing the above mentioned crops in the study area respectively. The results revealed that cassava, yam, coco yam, ground nut, black beans and bambara nut production in the study area were mainly dependent on direct energy source that dominated by human labour, while maize and rice production in the study area were dependent on indirect energy source that dominated by machinery, planting material and fertilizer. The average percentage renewable forms of energy input for producing all the crops mentioned above were 73%, 62.5%, 86%, 76%, 73.38%, 73.37%, 70.38% and 69.39% as against non-renewable form of energy used which were 27%, 37.50% 14%, 24%, 26.62%, 26.63% 29.62% and 30.69% respectively. The research results indicated that the current energy pattern used among the investigated farms in the study area were based on renewable energy in production of the above selected major food crops. The low utilization of non-renewable energy in the production of the above selected crops indicated that production of these crops were dependent mainly on human labor. The non-utilization of fossil fuel on the production of these crops may lead to environmental problems such as land and water pollution.

On the other hand, there is more of non-commercial form of energy input than commercial form among the selected food crop production. The reduction in consumption of commercial energy has a direct bearing on the cost of cultivation as reported by Singh et al, (2007).

The overall energy use ratio (OEUR) was determined from the ratio of total energy output to the total energy input (Table 14). The food crop with OEUR value less than or equal to one (1) indicated that the food crops production system is gaining energy or else losing energy. The results demonstrated that cassava and coco yam farmers have shown efficiency use of energy resources.

The average yields of cassava and coco yam were about 19718 kg/ha and 32400 kg/ha and its energy equivalent were calculated to be 71,940MJ and 79200 MJ respectively. Based on these values, the energy efficiencies for the production of cassava and coco yam were 6.5 and 2.2. The higher energy efficiency values indicated that higher yield per hectare were obtained in the study area within the study period. The food crop with OEUR value greater than two indicated that the food crops production system is losing energy. The average yields of yam and maize were about 64000 kg/ha and 60776 kg/ha and its energy equivalent were calculated to be 42750 MJ and 25560 MJ respectively. Based on these values, the energy efficiencies for the production of yam and maize were 1.89 and 1.68. The low energy efficiency values indicated that poor yield per hectare were recorded in the study area within the study period. The research study showed that Enugu State produced cassava and coco yam in abundant and less yam and maize within the period of research.

4. CONCLUSION AND RECOMMENDATION

The total energy cost inputs for food crops production in the study area within the research period were N324,600, N355,800, N626,800, N587,400, N308,400, N314,860, N318,100 and N311,660 for Cassava, Maize, Yam, Coco yam, Rice, Ground nut, Black beans and Bambara nut respectively. Total energy cost outputs were N659,200, N711,600, N1,253,600, N1,174,800, N616,800, N629,720, N636,200 and N623,320 for Cassava, Maize, Yam, Coco yam, Rice, Ground nut, Black beans and Bambara nut respectively. Energy output-input ratio was calculated as 6.5 for Cassava, 1.68 for Maize, 1.89 for Yam, 2.2 for Coco yam, 5.2 for Rice, 1.57 for Ground nut, 1.32 for Black beans and 1.45 for Bambara nut. The direct, renewable and non-commercial energy were the main energy cost consumed in the production of all the food crops except maize and rice that consumed more of indirect source of energy for the production in the study area. It was observed that, land preparation operation activities consumed the highest energy cost for the various food crops except for cassava and yam that recorded highest at planting and harvesting operations. The research results indicated that the energy form used among the investigated farmers were based on renewable and commercial form of energy on the selected food crops produced.

The proportion of non-renewable energy was low, which showed the food crops production depend mainly on manual labour in the research area. The research results would serve as guide for large, medium and small scale cassava, maize, yam, coco yam, rice, groundnut, black beans and bambara nut producers in the study area during policy making, planning and action taken as well as the government or any other stakeholder of these food crops production around the globe.

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The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Abubakar, M.S and Ahmed, D. (2010), "Pattern of Energy Consumption in Millet Production for Selected Farms in Jigawa Nigeria," Australian Journal of Basic and Applied Sciences, 4(4), 665 -672
2. FAO, (2012) Food and Agricultural Organization of the United Nations; The State of Food Insecurity in the World 2012, Economic Growth in Necessary but not Sufficient to Reduction of Hunger and Malnutrition Rome: FAO. (Available from <http://www.fao.org/publications/sofi/ent>
3. Hatirli, S.A., Ozkan, B and Fert, C (2006), "Energy Inputs and Crop Yield Relationship in Greenhouse Tomato Production", Renewable energy, 31(4), 738-744.
4. Jekayinfa, S.O and Bamgboye, A.I (2007), "Development of Equations for Estimating Energy Requirement in Palm-kernel Oil Processing Operations," Journal of Food Engineering, 79(4), 322 - 329.
5. Kizilaslan, H (2009), "Input-Output Energy Analysis of Cherries production in Takat Province of Turkey," Applied Energy 86(8), 1354-1358

6. Norman, M.J.T. (1978), "Energy Input and Outputs of Subsistence Cropping Systems in the Tropics," *Agro-Ecosystems*, 4(3), 355-366.
7. Odigboh, E.U (2002). Level of Agricultural Mechanization in Nigeria, in "Agricultural Engineering in Nigeria: 30 years of University of Ibadan Experience" Edited by Ajav, E.A; A.O. Raji, Ewemoje, T.A; Pages 42-56.
8. Ozkan, B, Akcaoz, H. and Fert, C (2004), "Energy Input-Output Analysis in Tunkish agriculture, "renewable energy, 29, 39-51
9. Pervanchon, F., bockstaller, C and Girardin, P. (2002), "Assessment of Energy use in Arable Farming Systems by means of an Agro-Ecological Indicator," the *Energy Indicator Agricultural Systems*, 72:149-172
10. Pimentel, D., (2008), "Biofuel, Solar and Wind as Renewable Energy System, Benefit and Risks, "Springer, Dordrecht. *The nether lands*, 8(7) 504 - 506
11. Singh, H, Mishra, D., and Nahar, N.M. (2002), "Energy use Pattern in Production Agriculture of A Typical Village in arid Zone of India-Part1", *Energy Conversion and Management*, 43(16), 2275 - 2286.
12. Singh, H., Singh, A.K; Kushawaha H.L and Singh, A (2007), "Energy Consumption Pattern of Wheat production in India," *Energy System*, 32-(8), 1848-1854.
13. Singh, S., S.R Verma and J.P. Mittal (1997), "Energy Requirements for Production of major Crops in India," *Agricultural Mechanization in Asia, Africa and Latin America*, 28(4): 13-17
14. Strapatsa, A.V., Nanos. G.D and Tsatsarelis, C.A (2006), "Energy Flow for Integrated Apple Production in Greece," *Agric. Ecosyst. Environ.* 116, 176-180.
15. Tripathi, R.S; and Sah, V.K. (2001), "Material and energy flows valley Farming Systems of Garhwal Himalaya," *Agric.. Ecosyst. Environ*, 86, 75-91
16. World Bank (2012). <http://www.tradingeconomics.com/nigeria/crop-production-index>